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Dear Sir:

Transmitted herewith for filing is the patent application and oath of the inventor(s): BLAIR LEWIS STRINGAM, KATHLEEN H. FRIZELL and BRENT W. MEFFORD

For: CONTINUOUS FLOW MEASUREMENT RECORDER AND RECORDING METHOD (REC-3653)

Date executed: July 28, 2000

Enclosed are also:

[X] 2 sheet(s) of drawing(s).

Claims as Filed

Claims	Number Filed	Number Extra	Rate X	Basic Fee \$690.00
Total Claims	12 - 20	0	\$18	= \$ -0-
Independent Claims	2 - 3	0	\$78	= \$ -0-
Total Filing Fee				\$690.00

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To the best of my knowledge and belief, the information contained on the cover sheet is true and correct and any copy submitted is a true copy of the original document.

Please address any correspondence to the undersigned attorney.

Respectfully submitted,



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# CONTINUOUS FLOW MEASUREMENT RECORDER AND RECORDING METHOD

## FIELD OF THE INVENTION

The present invention relates to a method and system for measuring and recording the flow rate of water in an open channel. More particularly, the present invention relates to a compact, readily transportable, continuous flow measurement recorder for a flume or weir or the like and to a corresponding recording method.

## BACKGROUND OF THE INVENTION

Historically, flow measurement through flumes or over weirs has been accomplished by carrying out manual measurements using a staff gauge. These manual measurements required management personnel or farmers to read water levels and look up the corresponding flow rate from a table. These manual measurements cannot be taken on a continuous basis, and this creates inaccuracies in the estimation of water flow. In addition, events, such as the change of water levels between manual measurements creates inaccuracies in the measurement. These inaccuracies result in the delivery of too much or too little flow volume in irrigation related applications.

Chart recorders, such as the Stevens Recorder, have also been used in the past. The chart recorder prints a running record of the water level on a paper chart. A stilling well and enclosure are required for the proper operation. These devices are mechanical and require considerable maintenance. In addition, the chart records are tedious to read and do not permit simple, quick flow evaluation.

Data logging instrumentation equipment can be adapted to record a continuous flow record but this equipment is complex and exceeds continuous flow recording requirements.

## SUMMARY OF THE INVENTION

In general, the present invention is concerned with a recording method and a recorder device that provides easy, low-cost, continuous readout and recording of flow volumes in open channel flow measurement operations upstream of flumes or weirs. The invention has broad application to thousands of water diversions which are currently being made without accurate flow measurement, and will permit the water manager, whether a governmental agency, irrigation district, private firm or individual farmer, to manage and conserve water.

In accordance with a first aspect of the invention, a continuous flow measurement recorder is provided for determining and displaying water flow in an open channel, the continuous flow measurement recorder comprising: a sensor for determining, using a measurement structure in the open channel, the pressure head of water flowing in the open channel and for producing a corresponding output signal; a central processing unit for receiving the output signal from said sensor, for calculating total water flow in the channel based on the output signal and for producing a total flow signal based on the calculated total water flow; a display device for receiving the total flow signal from said central processing unit and for displaying total flow based thereon; and a single housing for housing the sensor, central processing unit, and display device.

In an advantageous implementation, the sensor comprises an ultrasonic sensor and said measurement structure comprises a weir or flume.

The display device preferably comprises a liquid crystal display device.

The housing advantageously comprises a top portion and a bottom portion mechanically connected to the top portion. The housing preferably further comprises a downwardly depending member connected to the bottom portion of the housing, and the sensor is preferably received in said member.

The central processing unit preferably determines average pressure head in the channel over a predetermined period of time based on the output signal received from the sensor, and stores the average pressure head in memory and uses the stored pressure head to calculate total flow. Advantageously, the central processing unit stores, in memory, values for a constant coefficient,  $C$ , and an exponent,  $n$ , both based on the characteristics of the measurement structure used, and uses these values to convert said average pressure head into a value for the flow discharge rate,  $Q$ , using the equation:  $Q = Ch_a^n$ , where  $h_a$  is equal to the average pressure head over said predetermined period of time. The central processing unit converts the flow discharge rate,  $Q$ , into a total flow value,  $T_f$ , using the equation:  $T_f = T_i + Qt$ , where  $t$  is equal to said predetermined period of time and  $T_i$  is a previously determined value for total flow of the beginning of period  $t$ .

In accordance with a further aspect of the invention, a method is provided for determining and displaying the total water in an open channel, the method comprising: using a sensor to obtain a plurality of pressure head measurements for water flowing

through a measurement structure in the open channel over a predetermined period of time; using a central processing unit to determine an average pressure head measurement for the open channel for said predetermined period of time and to convert the average head measurement into a value representing total flow in the channel; and using a liquid crystal display device housed in a common housing with the sensor and the central processing unit to display the total flow value.

Advantageously, the average head measurement is converted into a value representative of the flow rate and the incremental flow discharge rate value is summed so as to produce the total flow value. The average head measurement is converted into a value representative of the discharge rate  $Q$ , using the equation:  $Q = Ch_a^n$ , where  $h_a$  is the average head measurement, and  $C$  is a constant coefficient, and  $n$  is an exponent, both based on the characteristics of the measuring structure used.

Preferably, the discharge rate  $Q$  is converted into a value  $T_f$  representative of total flow using the equation:

$T_f = T_i + Qt$ , where  $t$  is said predetermined period of time and  $T_i$  is a previously determined value for total flow at the beginning of the time period  $t$ .

Further features and advantages of the present invention will be set forth in, or apparent from, the detailed description of preferred embodiments thereof which follows.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of a preferred embodiment of the overall continuous flow measurement system of the invention, including block diagram and schematic circuit diagram representations of the basic units or elements thereof;

Figure 2 is a side view of the preferred embodiment of the continuous flow measurement system of the invention, showing the common housing; and

Figure 3 is a transverse cross-sectional view of the embodiment of Figure 2.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figures 1 to Figure ~~3~~<sup>4</sup>, there is shown a continuous flow measurement system in accordance with a preferred embodiment of the invention. The measurement system, which is generally denoted 10, includes a display device 12, a central processing unit (CPU) 14, and a water-level sensor 16 housed within a housing unit 18.

The water-level sensor 16, the CPU 14, and the display device 12 cooperate to measure, calculate and display the total water flow. In general, as shown in Figure ~~10~~<sup>2</sup>, the device 10 (including the water-level sensor 16) is positioned relative to a measurement structure such as a flume or weir, indicated schematically at F, so as to measure the open channel head,  $h_a$ , of a channel indicated at C, and the output of the water-level sensor 16 is connected to the CPU 14 which uses measurements from the water-level sensor 16 to determine the total flow,  $T_f$ . The CPU 14 is connected to the display device 12 and transmits total flow,  $T_f$ , measurements for display by device 12.

As can be seen in Figures 3 and 4, the housing unit 18 provides a mounting for the display device 12, the CPU 14, and the water-level sensor 16 and because of the compact nature of the housing 18 the device 10 can be readily transported and installed.

In a preferred embodiment, as shown in Figures 3 and 4, the housing 18 is of a two piece or two component construction, comprising top or cover 18a and bottom or base portion 18b. The housing components, 18a and 18b, are connected together by conventional mechanical fastening indicated at 18c.

The CPU 14 stores head measurements and total flow measurements in memory along with discharge coefficients, C, and exponents, n, described below, used in stored equations that are used to calculate the total flow.

As shown in Figures 3 and 4, the water-level sensor 16 is mounted in a downwardly depending member which is secured to the bottom of the base portion 18b of housing 18 by a screw threaded mounting element 22. The water-level sensor 16 comprises an ultrasonic sensor, although other suitable water level sensors can be used in some applications.

Display device 12 preferably comprises a liquid crystal display and is mounted at the top of housing 18 for convenient viewing in the example embodiment shown in Figure <sup>3</sup>~~3~~ and <sup>4</sup>~~4~~. A viewing window 24 protects the LCD 12. CPU 14 is connected to LCD 12 through three wires or connectors W1, W2 and W3. Wire W1 is for power (5 Vdc), wire W2 carries the digital display signal and wire W3 is connected to ground.

A power source in the form of a battery 26 and solar panel 28 provides DC supply voltage for CPU 14, although a different DC power source can be used.

The system 10 is particularly useful in agricultural applications to determine the total flow of water through an open channel C, as measured by a flume indicated at F in Figure 2, where the typical units for total flow are acre/ft. The system 10, of course, can also be used to determine total flow in other units. The system 10 determines the total flow according to the equations:

$$Q = Ch_a^n \quad (\text{eq. 1})$$

where:

Q = discharge (ft<sup>3</sup>/s)  
 C = coefficient for the particular measuring structure  
 h<sub>a</sub> = measuring head on the flume or weir  
 n = exponent value for the particular measuring structure

and

$$T_f = T_i + Qt/43560 \quad (\text{eq. 2})$$

where:

T<sub>f</sub> = total flow (acre/ft.)  
 T<sub>i</sub> = total flow (acre/ft.) determined previous  
 Q = discharge  
 t = time (s)

In operation, the ultrasonic water-level sensor 16 continuously measures the head, h<sub>a</sub>, on the flume or weir F, and supplies these measurements to the CPU 14. The CPU 14 stores measurements over a predetermined period of time in order to determine the average pressure head over that period. The CPU 14 converts the average pressure head into a value for flow discharge Q, using equation 1, and into a



total flow value, using equation 2. The CPU 14 supplies the values to the display device 12 for display thereby.

It should be noted that total flow can, of course, be computed in other units besides acre feet, but that acre feet is commonly used by irrigators. As equation 2 indicates, the total flow is summed each time the flow rate is calculated. In order to accomplish this, the CPU 14 must record and use the time interval between the last flow rate measurement and the present flow rate measurement. Considering a specific, non-limiting example calculation for a flume with a "C" value of 3.359, an "n" value of 1.57, a "h<sub>a</sub>" of 1.24 ft., a previous measured total flow of 2.34 acre feet, and a time interval of 600 s, the calculated values for Q and T<sub>f</sub> are

$$Q = 3.359 (1.24^{1.57}) = 4.71 \text{ ft}^3/\text{s}$$

$$T_f = 2.34 + (4.71 (600))/43560 = 2.40 \text{ acre feet.}$$

Although the invention has been described above in relation to preferred embodiments thereof, it will be understood by those skilled in the art that variations and modifications can be effected in these preferred embodiments without departing from the scope and spirit of the invention.

WHAT IS CLAIMED IS:

1. A continuous flow measurement recorder for determining and displaying water flow in an open channel, said continuous flow measurement recorder comprising:
  - a sensor for determining, using a measurement structure in the open channel, the pressure head of water flowing in the open channel and for producing a corresponding output signal;
  - a central processing unit for receiving said output signal from said sensor, for calculating total water flow in the channel based on said output signal and for producing a total flow signal based on the calculated total water flow;
  - a display device for receiving said total flow signal from said central processing unit and for displaying total flow based thereon; and
  - a single housing for housing said sensor, said central processing unit, and said display device.
2. The continuous flow measurement recorder of claim 1 wherein said sensor comprises an ultrasonic sensor and said measurement structure comprises a weir or flume.
3. The continuous flow measurement recorder of claim 1 wherein said display device comprises a liquid crystal display device.

4. The continuous flow measurement recorder of claim 1 wherein said housing comprises a top portion and a bottom portion mechanically connected to the top portion.

5. The continuous flow measurement recorder of claim 4, wherein said housing further comprises a downwardly depending member connected to said bottom portion of said housing, and wherein said sensor is received in said member.

6. The continuous flow measurement recorder of claim 1 wherein said central processing unit determines average pressure head in the channel over a predetermined period of time based on said output signal received from said sensor, and stores said average pressure head in memory and uses said stored pressure head to calculate total flow.

7. The continuous flow measurement recorder of claim 6 wherein said central processing unit stores, in memory, values for a coefficient, C, and an exponent, n, both based on the characteristics of the measurement structure used and uses said values to convert said average pressure head into a value for the flow discharge rate, Q, using the equation;

$$Q = Ch_a^n$$

where  $h_a$  is equal to the average pressure head over said predetermined period of time.

8. The continuous flow measurement recorder of claim 7 wherein said central processing unit converts the flow discharge rate, Q, into a total flow value, T<sub>f</sub>, using the equation:

$$T_f = T_i + Qt$$

where t is equal to said predetermined period of time and T<sub>i</sub> is a previously determined value for total flow of the beginning of period t.

9. A method for determining and displaying the total water in an open channel, said method comprising:

using a sensor to obtain a plurality of pressure head measurements for water flowing through a measurement structure in the open channel over a predetermined period of time;

using a central processing unit to determine an average pressure head measurement for the open channel for said predetermined period of time and to convert said average head measurement into a value representing total flow in the channel; and

using a liquid crystal display device housed in a common housing with said sensor and said central processing unit to display said total flow value.

10. The method of claim 9 wherein the average head measurement is converted into a value representative of the flow rate and said flow discharge rate value is converted into said total flow value.

11. The method of claim 10 wherein the average head measurement is converted into a value representative of the discharge rate Q, using the equation:

$$Q = Ch_a^n$$

where  $h_a$  is the average head measurement, and C is a coefficient, and n is an exponent, both based on the characteristics of the measuring structure used.

12. The method of claim 10 wherein the discharge rate Q is converted into a value  $T_f$  representative of total flow using the equation:

$$T_f = T_i + Qt$$

where t is said predetermined period of time and  $T_i$  is a previously determined value for total flow at the beginning of the time period t.

## ABSTRACT OF THE DISCLOSURE

A continuous flow measurement recorder is provided for making water flow measurements in an open channel. An ultrasonic sensor obtains pressure head measurements upstream from a flume or weir located in the open channel. A central processing unit receives the head measurements from the sensor and calculates the water flow rate and the total flow. A liquid crystal display device displays the water flow rate and total water flow calculated by a central processing unit. A common, portable, easy to install housing is used to house and protect the sensor, central processing unit, and display device.

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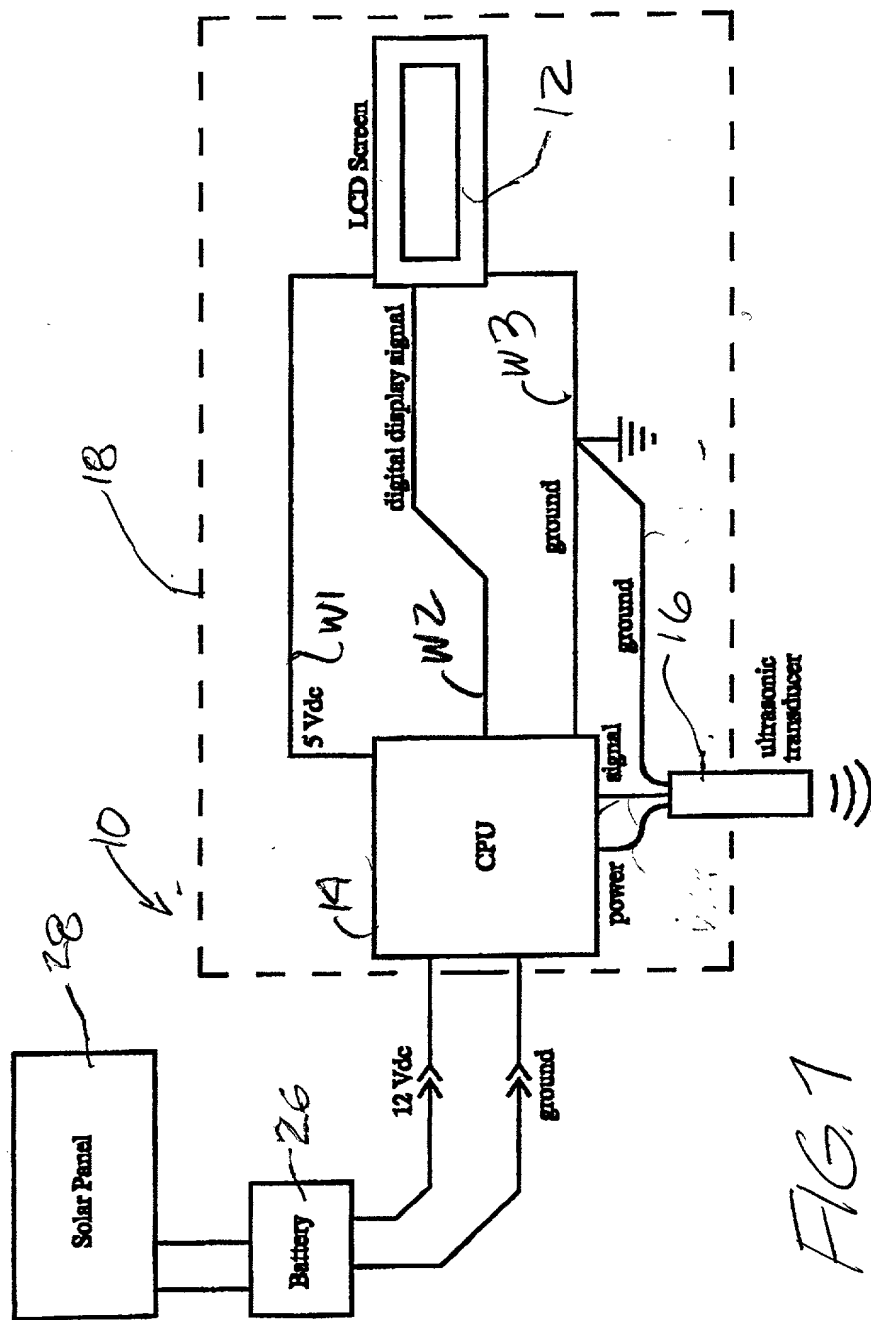


FIG. 1

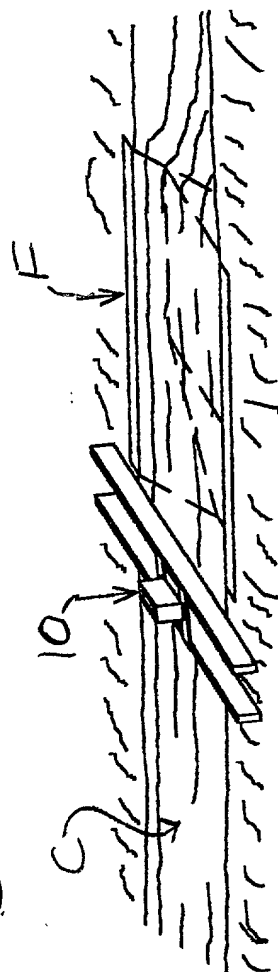
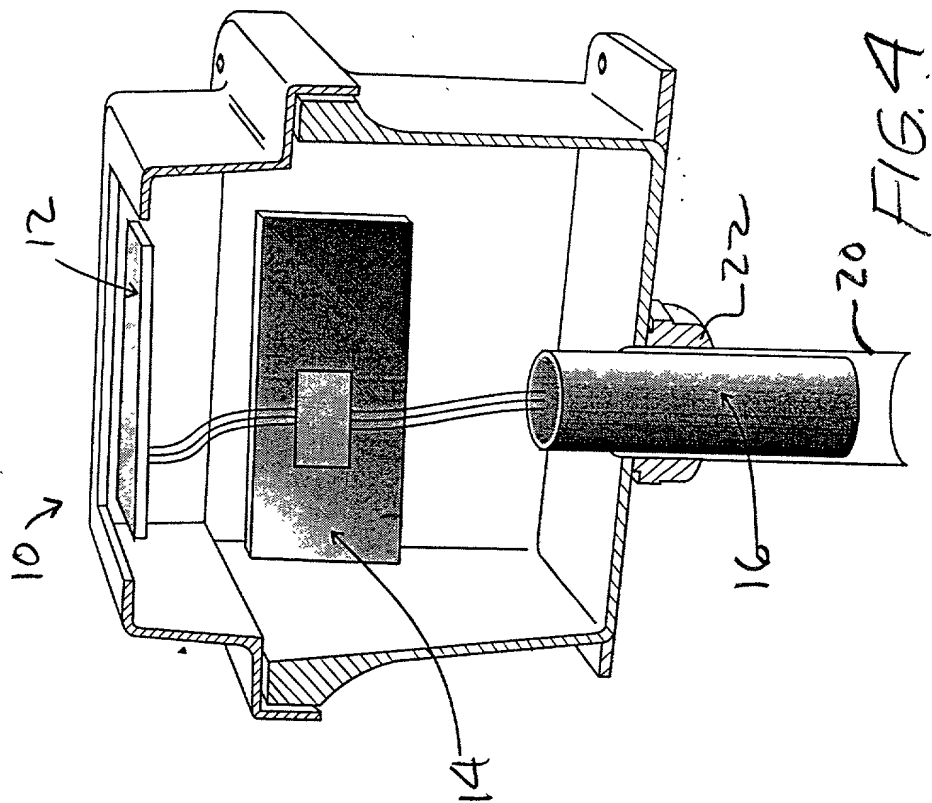
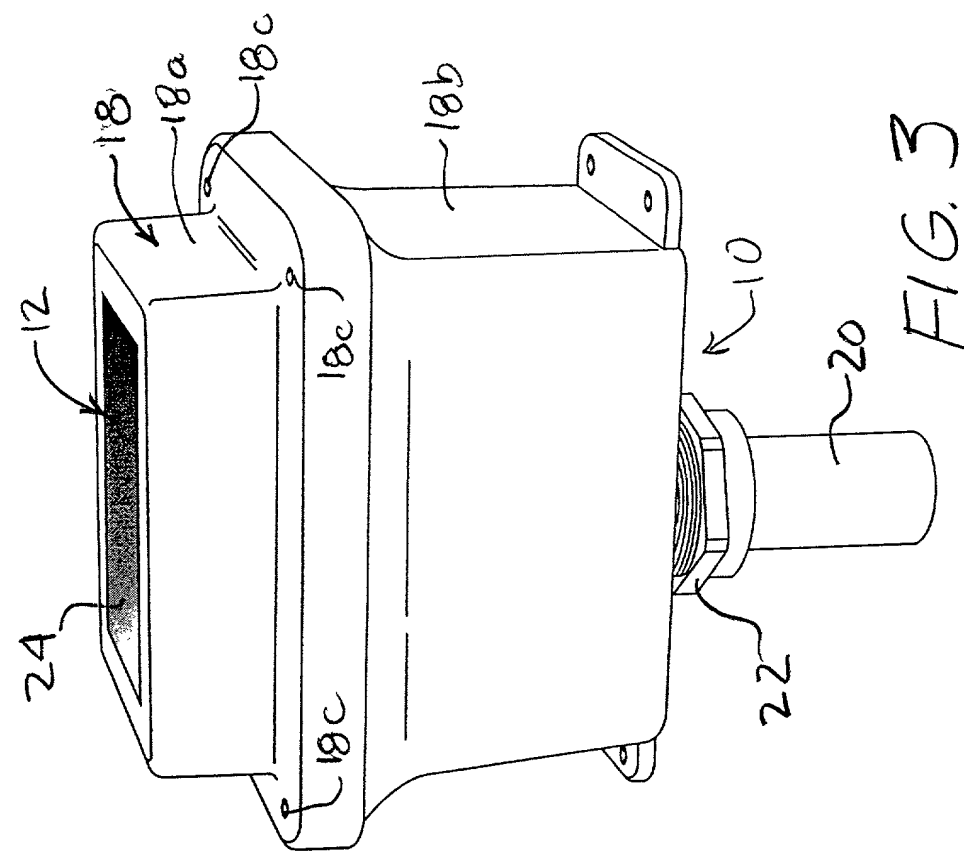


FIG. 2





**DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION**  
**English Language Declaration**

As below named inventors, we hereby declare that:

Our residences, post office address, and citizenships are as stated below next to our names.

We believe we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**"CONTINUOUS FLOW MEASUREMENT RECORDER AND RECORDING METHOD"(REC-3653)**

the specification of which (check one):

☒ is attached hereto.

☐ Was filed on \_\_\_\_\_ as

Application Serial No. \_\_\_\_\_  
and was amended on \_\_\_\_\_ (if applicable)

We hereby state that we have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to in the oath or declaration.

We acknowledge our duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

We hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
(Number)	(Country)	(Day/Month/Year Filed)	YES	NO
(Number)	(Country)	(Day/Month/Year Filed)	YES	NO
(Number)	(Country)	(Day/Month/Year Filed)	YES	NO

We hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, we acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
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(Application Serial No.)

(Filing Date)

(Status)  
(patented, pending,  
abandoned)

(Application Serial No.)

(Filing Date)

(Status)  
(patented, pending,  
abandoned)

We hereby declare that all statements made herein of our own knowledge is true and that all statements made on information and belief is believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

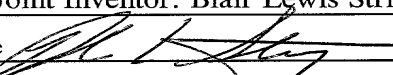
POWER OF ATTORNEY: As named inventors, we hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office in connection therewith.

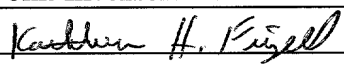
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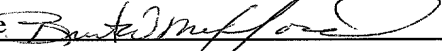
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